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Lab. Project 5046-3, Part 49
Final Report
NS 081-001

AW-7

MATERIAL LABORATORY

NEW YORK NAVAL SHIPYARD

BROOKLYN 1, N. Y.

TECHNICAL REPORT

SND-NYNS-900-P-1A

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Investigation of

SPECTRAL REFLECTANCE AND TRANSMITTANCE

of

INTERIOR FUEL MATERIALS

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Lab. Project 5046-3, Part 49
Final Report
NS 081-001
Technical Objective AW-7
AFSWP-394
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Final Report

ABSTRACT

The spectral reflectance and transmittance of twenty-one materials employed within and around dwellings have been determined by the Material Laboratory. The total radiant absorptances computed from these data for 2000°K and 6000°K black-body radiation may be significantly different, even for black materials. In estimating the thermal energy from a given source required to damage a material on the basis of measurements utilizing a source of different spectral quality, suitable correction must be made for the absorptance of the material integrated over the spectrum of the source.

CONTENTS

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Ref: (a) FPL, USFS, ltr R-PL, Cooperation, AFSWP to NML of 31 Mar 1953
(b) COMNYKNAVSHIPYD conf ltr S99/L5, Ser 960-92, of 15 Mar 1950
(c) BUSHIPS rest. spdltr. C-S99(0)(348), Ser 348-75, of 6 Apr 1950

Encl: (1) Spectral Characteristics of Various Materials (21 Figures)
(2) Radiant Absorptances of Materials

AUTHORITY

1. This investigation, which was requested by reference (a) and conducted by the Material Laboratory, is part of the program proposed by reference (b) and formally approved by reference (c). The general Thermal Radiation program is under the supervision of the Armed Forces Special Weapons Project.

INTRODUCTION

2. The Forest Products Laboratory, U.S. Forest Service, Madison, Wis., under contract to the Armed Forces Special Weapons Project, is studying the behavior, under exposure to intense thermal radiation, of various materials which may serve as fuels in the event of an atomic explosion over an urban area. In studying the ignition characteristics of these materials and in attempting to correlate laboratory and field exposures, involving a source of radiation of relatively low temperature and one of relatively high temperature, the spectral reflectance, transmittance and absorptance of the materials are important factors in attempting to predict their behavior under exposure to a nuclear detonation.

3. The materials investigated included those which would be found in the interior of and about a typical dwelling . The materials were selected and submitted by the Forest Products Laboratory. The measurements included the spectral reflectance and spectral transmittance of the materials over the spectral region from 0.3 to 2.7 microns; the total absorptances of the materials for black-body radiation at 2000°K and 6000°K were computed from these data.

METHODS OF MEASUREMENT

4. In general, the spectral transmittance and reflectance measurements were made over the spectral range from 0.32 to 2.7 microns. The Beckman Model DU Spectrophotometer[1] was employed for the measurements in the ultraviolet (0.32-0.4 microns). The General Electric Recording Spectrophotometer[2] was employed for the measurements in the visible and near-infrared regions (0.4-1.0 micron). For the transmittance measurements in the infrared region(1.0-2.7 microns), the Perkin-Elmer Infrared Spectrometer[3] was employed; for the reflectance measurements in the infrared region the spectrometer was used in conjunction with the NML-designed reflectometer[4]. Measurements were taken in overlapping spectral regions to enable correlation of data from the

1,2,3,4 See bibliography

three instruments. Readings were recorded at intervals of 20 millimicrons in the ultraviolet and visible regions and at intervals of 100 millimicrons in the infrared.

5. Difficulty of sample placement precluded taking transmittance measurements in the ultraviolet for certain materials such as excelsior and broom-straw, but since the transmittance of these materials is dependent on configuration and thickness, it may be assumed that the transmittance, at least to a first approximation, is negligible.

6. The accuracies of the reflectance measurements in the ultraviolet, visible, and infrared regions are approximately ± 4, ± 1, and ± 5 per cent, respectively. The corresponding values for the transmittance measurements are ± 2, ± 1, and ± 2 per cent, respectively. These figures give an overall accuracy of the absorptance measurements of about ± 5 per cent. While this accuracy will hold for a particular placement of such samples as shredded newspaper, excelsior, broom straw, scrub brush, dust mop, and cotton waste, slight changes in orientation or packing may produce large changes in reflectance. On the other hand, the measurements are useful for a comparison of the samples' radiant absorptance values relative to various sources.

RADIANT ABSORPTANCE

7. The total radiant absorptance, α, for a given material was computed from the spectral transmittance and reflectance as measured. It was defined by means of the relationship:

$$\alpha = \frac{\int_{.32\mu}^{2.7\mu} \alpha_\lambda E_\lambda \, d\lambda}{\int_{.32\mu}^{2.7\mu} E_\lambda \, d\lambda}$$

$$\alpha_\lambda = 1 - \rho_\lambda - t_\lambda$$

where α_λ, ρ_λ, and t_λ are the material's spectral absorptance, reflectance, and transmittance, respectively, at the wavelength λ; $E_\lambda d\lambda$ is the spectral

energy of the source in the wavelength interval from λ to $\lambda+d\lambda$.

8. The absorptance coefficients of the samples were computed for 2600°K and 6000°K black-body sources. No corrections were made for atmospheric losses.

RESULTS

9. The spectral transmittances and reflectances of the various materials are given in Enclosure (1). The total radiant absorptances are given in Enclosure (2).

10. Several observations may be drawn from the data presented in Enclosures (1) and (2). While color determines the amount of visible radiation a material may absorb, as Figures 1 and 2 show in the case of rayon twill linings, the reflectance and absorptance of a light-colored material in the infrared may be the same as those of a dark-colored material. The black materials are not black in the infrared. The transmittance of relatively opaque materials is significant in determining the amount of radiation a material may absorb. It is interesting to note that the spectral transmittance has the same general characteristic as the spectral reflectance. The cellulosic-base fibers (cotton, rayon and paper) have similar absorptance maxima in the infrared.

11. The data of Enclosure (2) indicate that, in correlating laboratory and field exposures, particularly when there is a substantial difference in the temperatures of the two sources, suitable correction must be made for the total radiant absorptance of the material for the particular source of radiation.

Approved:

H. T. Koonce

H T. KOONCE, CAPTAIN, USN
The Director

sm

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2. J.L. Michaelson, Construction of the General Electric Recording Spectrophotometer, J. Opt. Soc. Am., 28, 365 (1938)

3. R.B. Barnes, R.S. McDonald, V.Z. Williams, and R.F. Kinhaird, Small Prism Infra-red Spectrometry, J. App. Phys., 16, 77 (1945)

4. Naval Material Laboratory. A Reflectometer for Measuring Diffuse Reflectance in the Infrared Region. Final Report, Lab. Project 5046, Part 9 (1950).

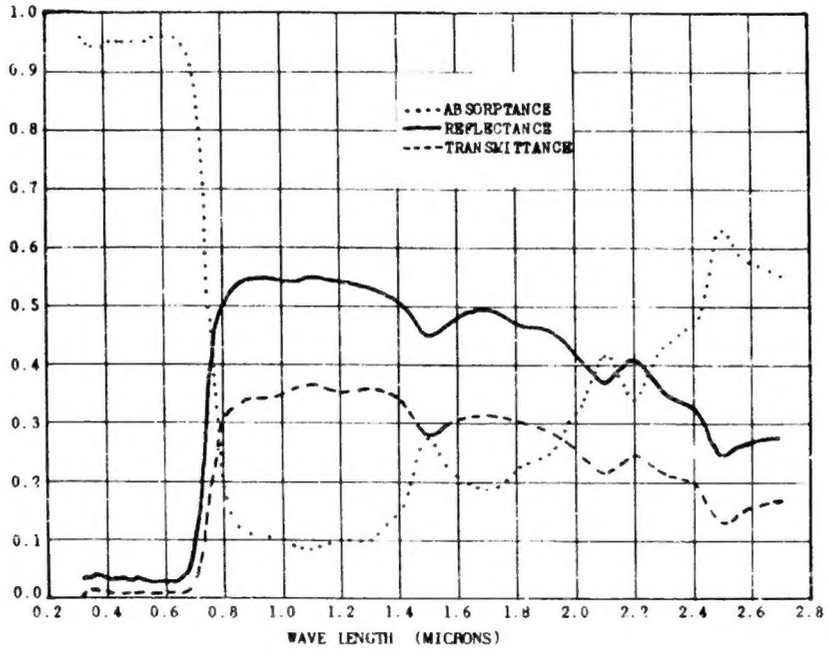

Fig. 1 Spectral Characteristics of Black Rayon Twill Lining

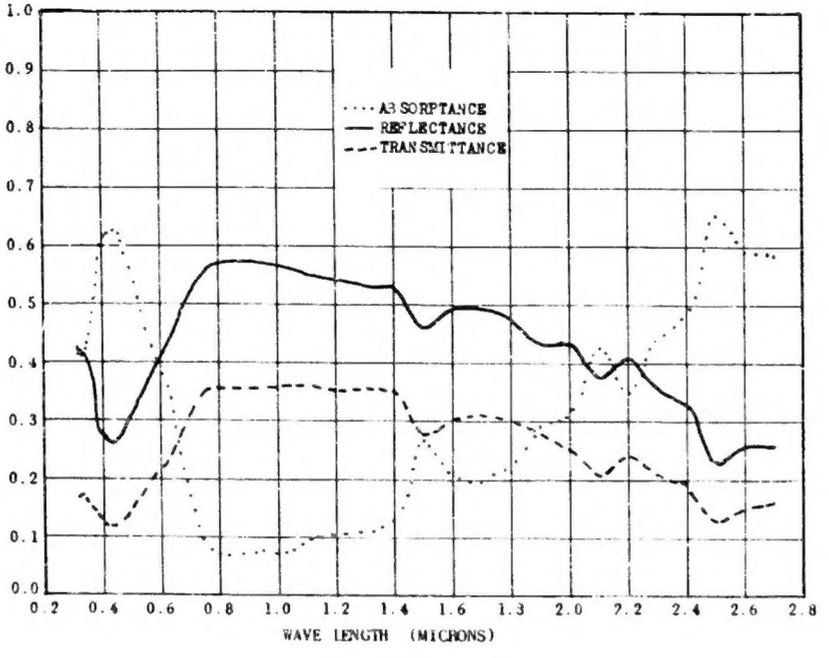

Fig. 2 Spectral Characteristics of Beige Rayon Twill Lining
Lab. Project 5046-3, Part 49 Enclosure (1)

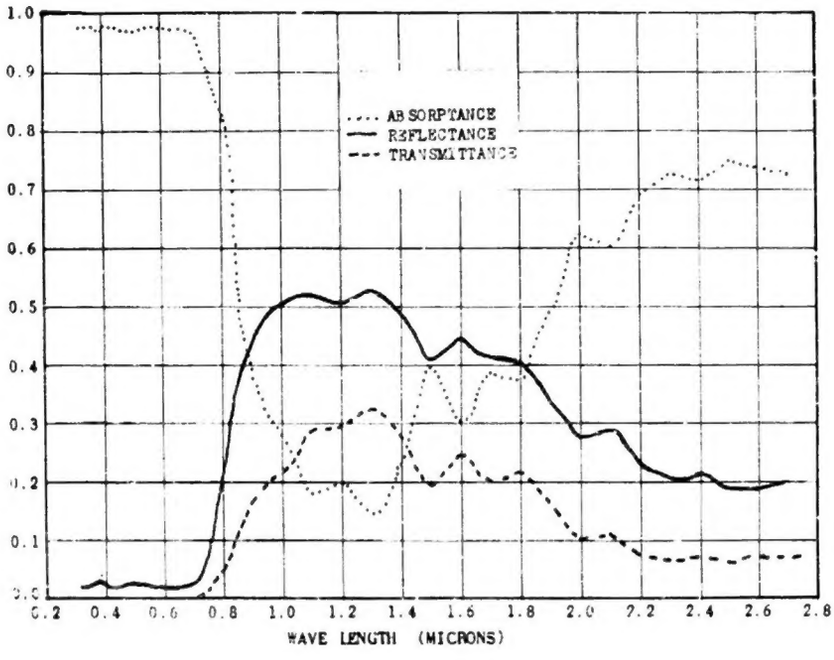

Fig. 3 Spectral Characteristics of Black Wool Flannel

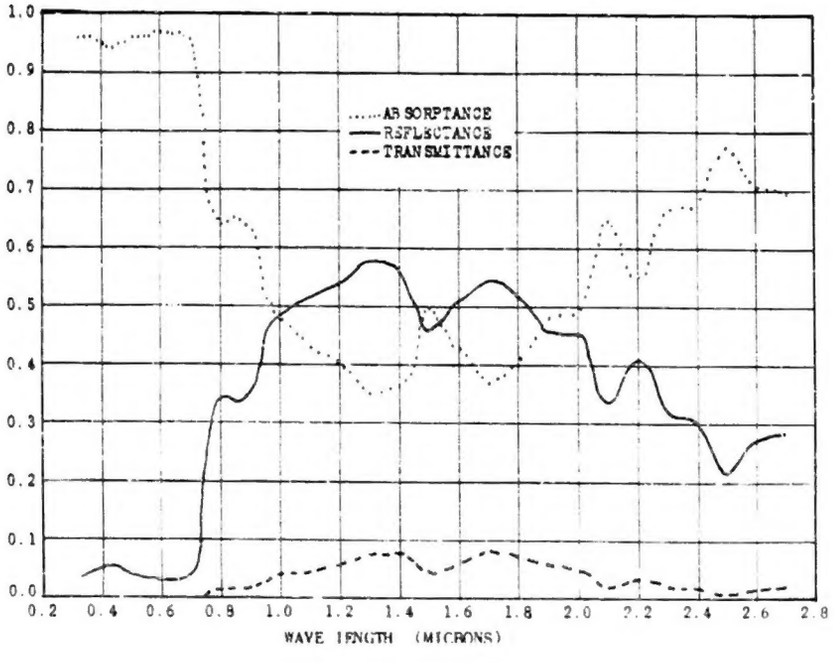

Fig. 4 Spectral Characteristics of Washed Blue Cotton Denim
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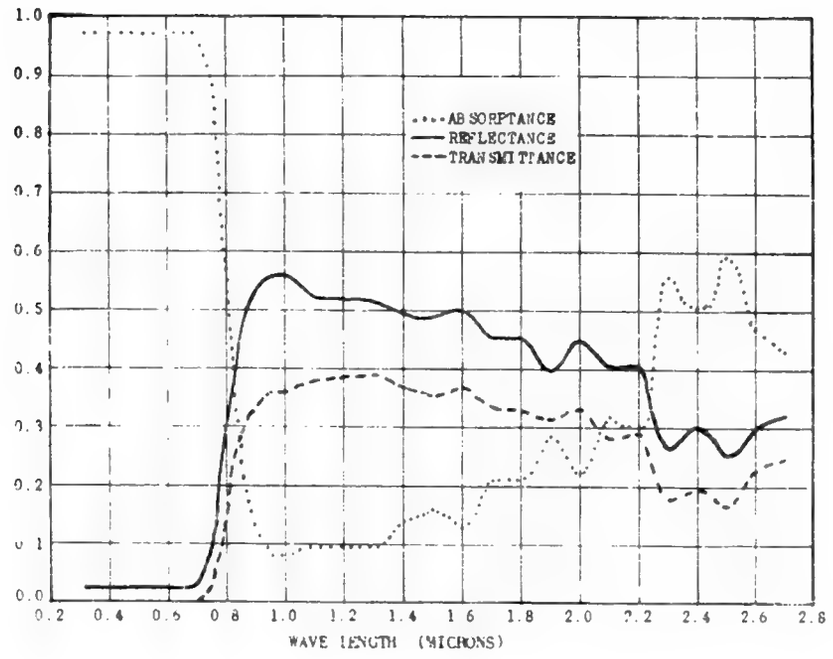

Fig. 5 Spectral Characteristics of Black Acetate Shantung

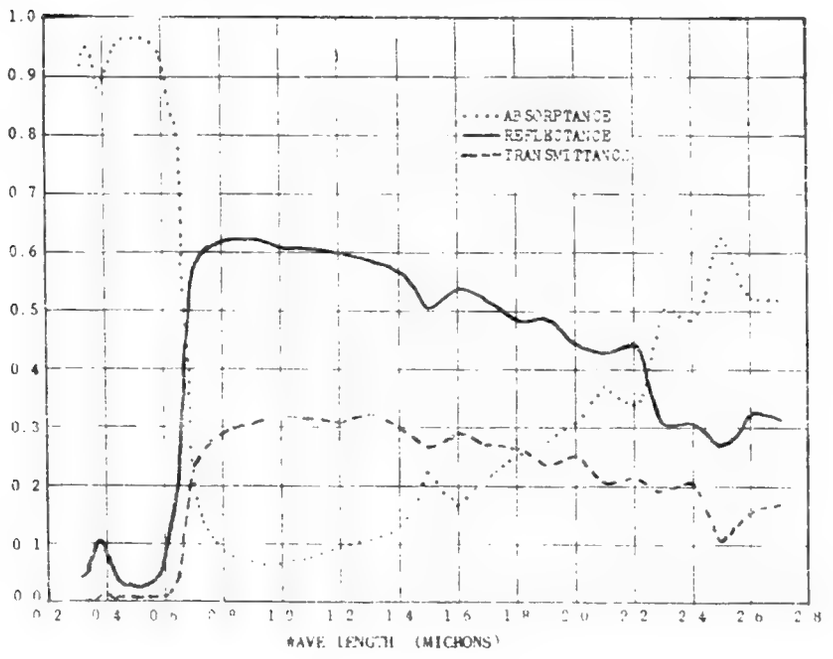

Fig. 6 Spectral Characteristics of Wine Rayon Acetate Drapery
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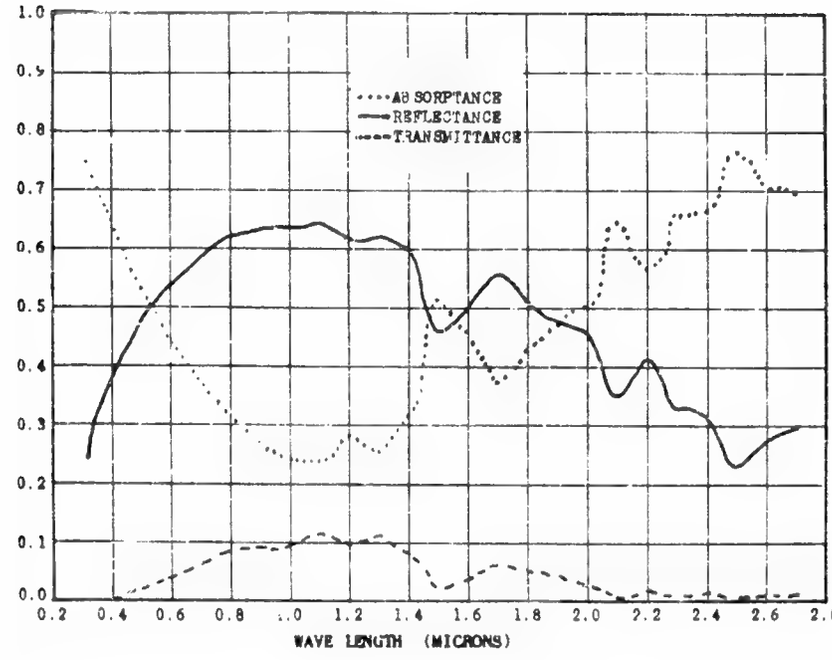

Fig. 7 Spectral Characteristics of Cream Color Venetian Blind Cotton Tape

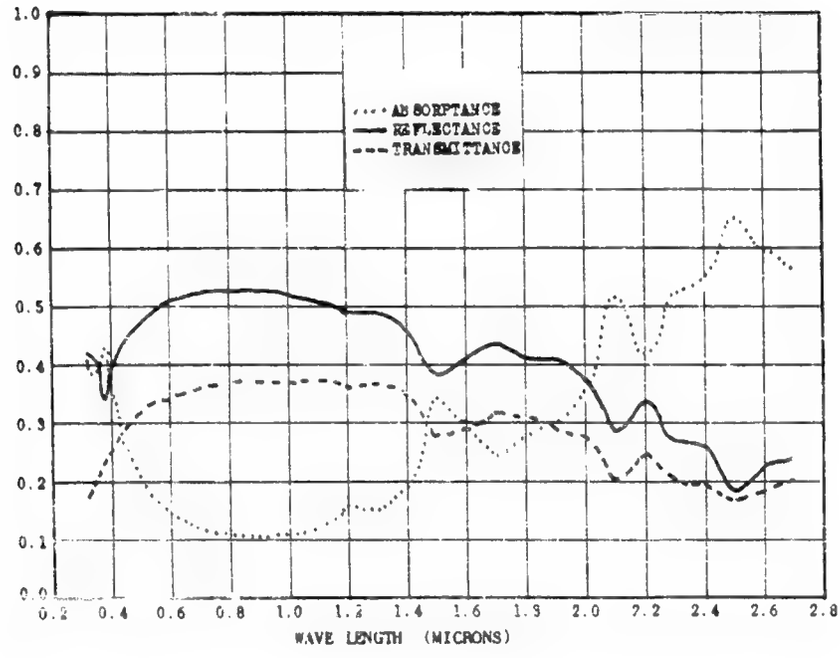

Fig. 8 Spectral Characteristics of Unbleached Cotton Sheeting
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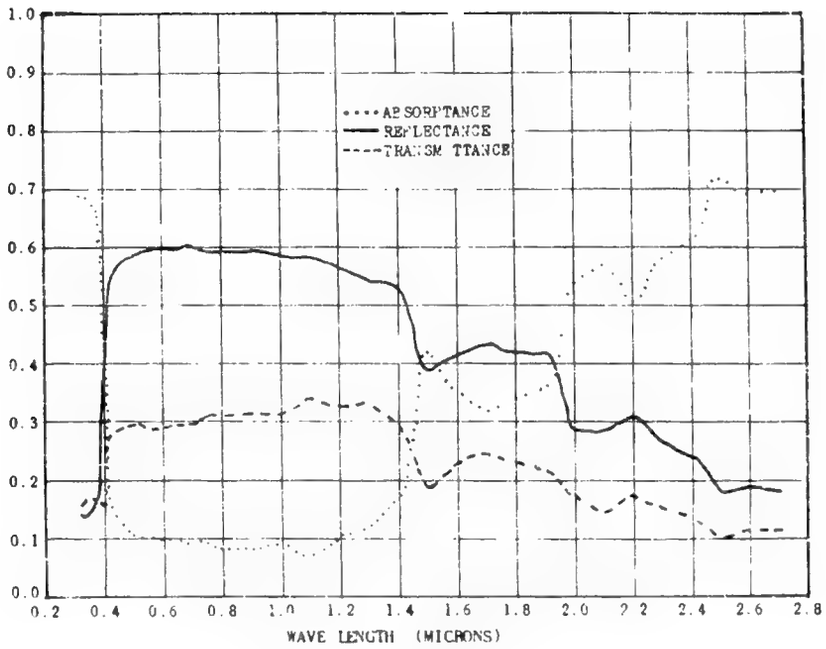

Fig. 9 Spectral Characteristics of Ivory-White Rayon Marquisette Curtain

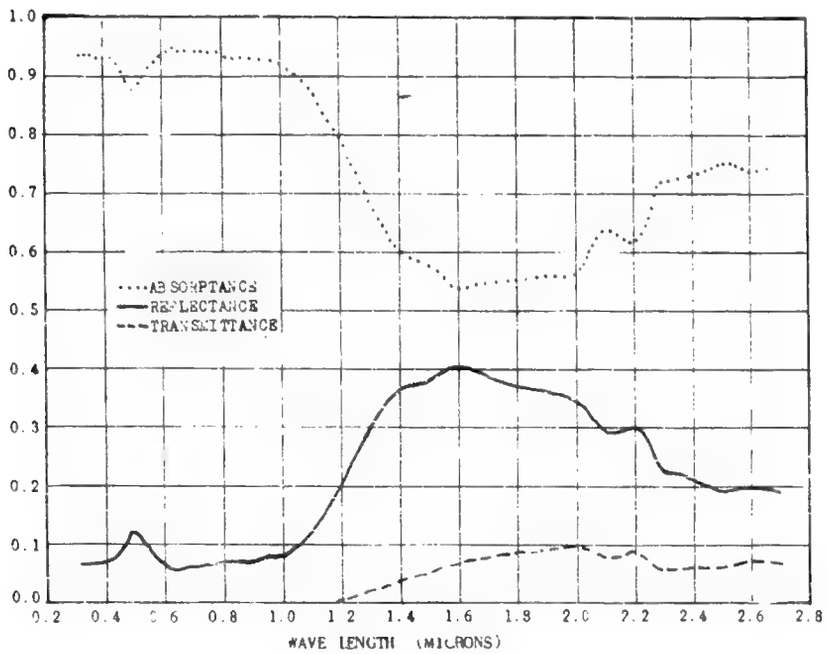

Fig. 10 Spectral Characteristics of Oiled Green Window Shade
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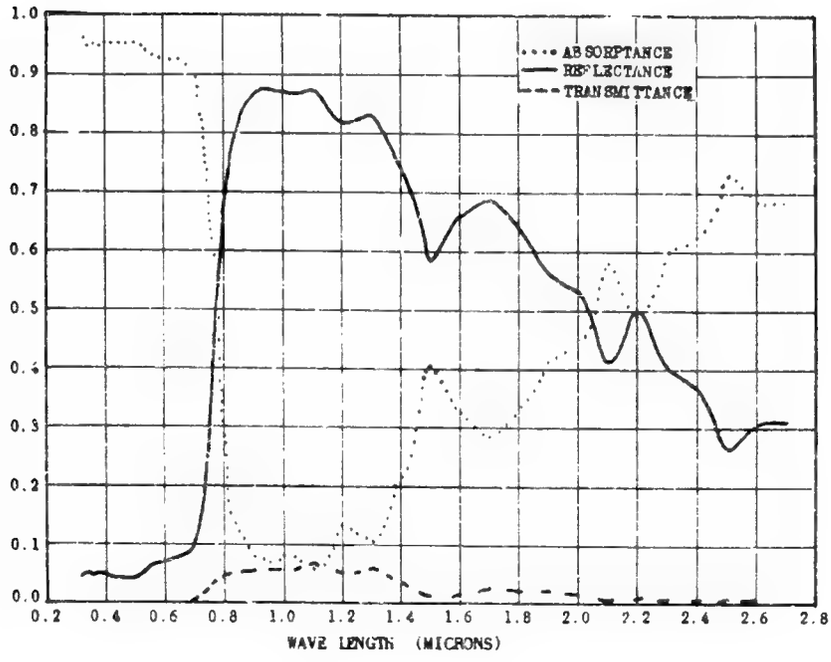

Fig. 11 Spectral Characteristics of 3-Ply Dark Bristol Board

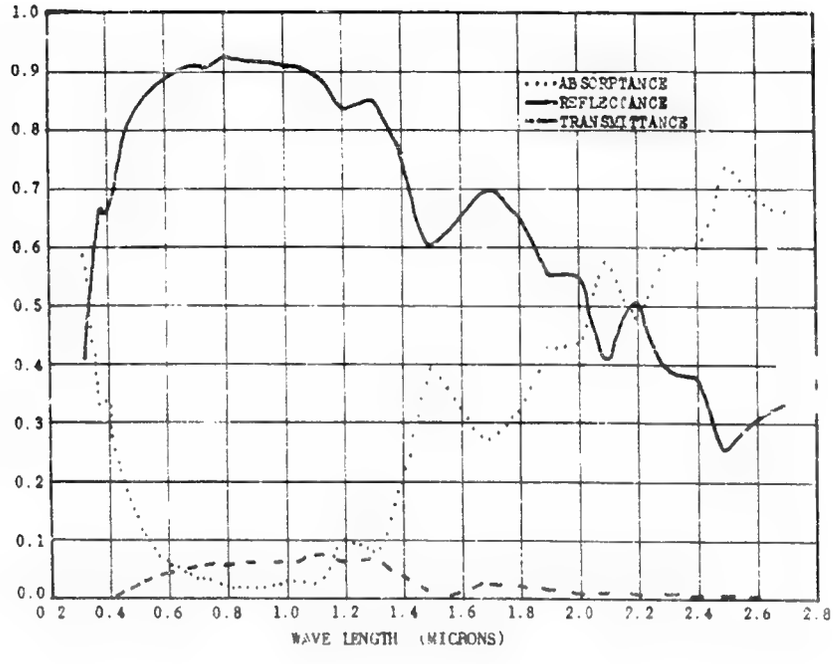

Fig. 12 Spectral Characteristics of 3-Ply White Bristol Board
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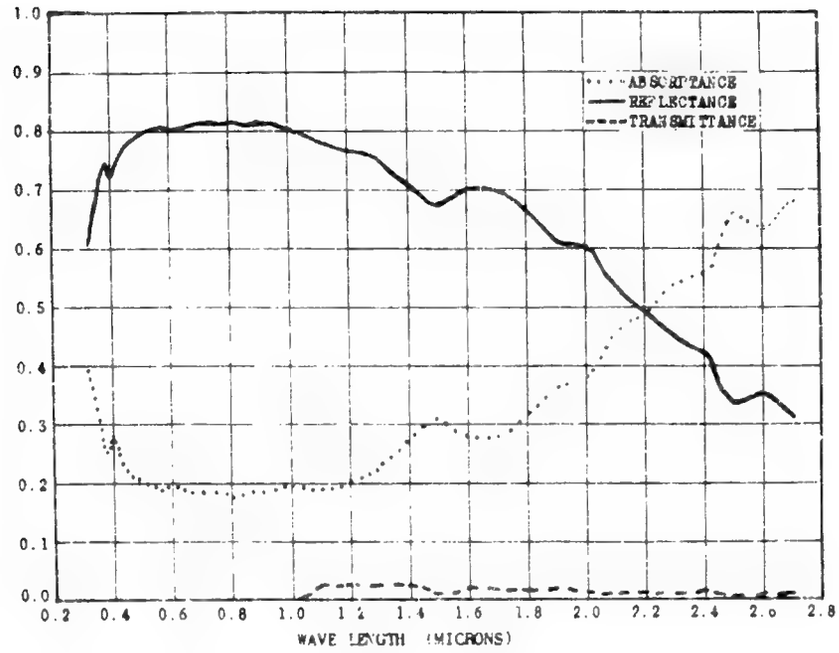

Fig. 13 Spectral Characteristics of 10-Ply White Bristol Board

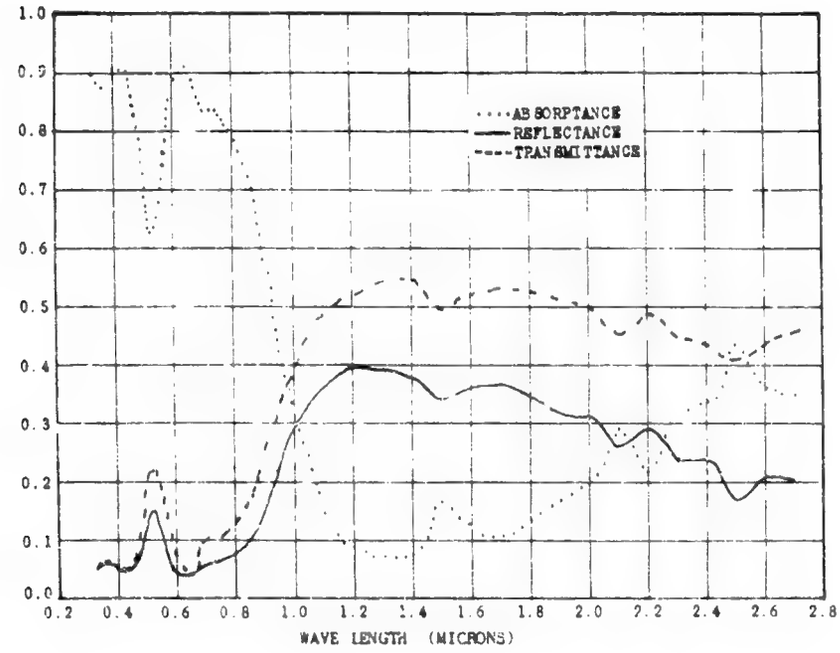

Fig. 14 Spectral Characteristics of Green Crepe Paper
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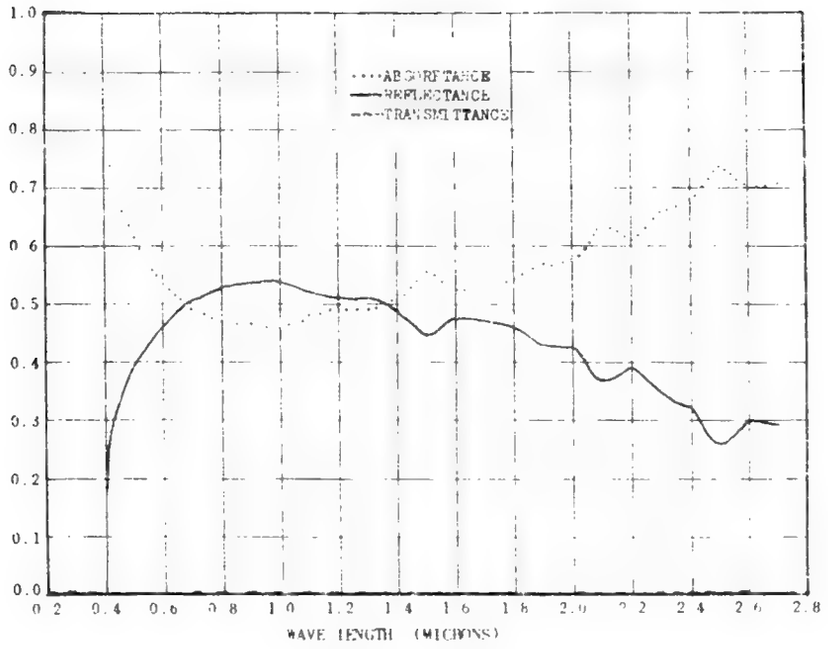

Fig. 15 Spectral Characteristics of Shredded Newspaper

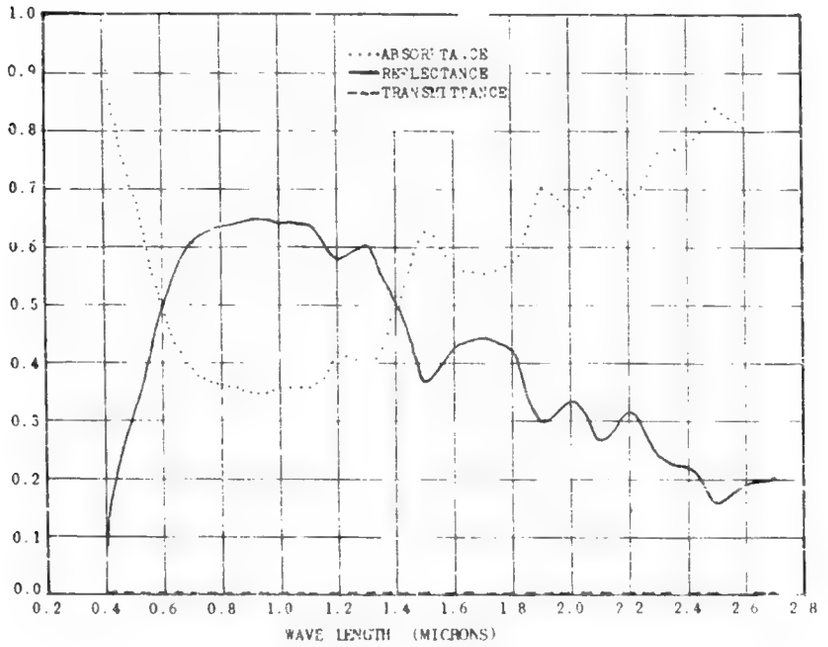

Fig. 16 Spectral Characteristics of Light Yellow Ponderosa Pine Excelsior
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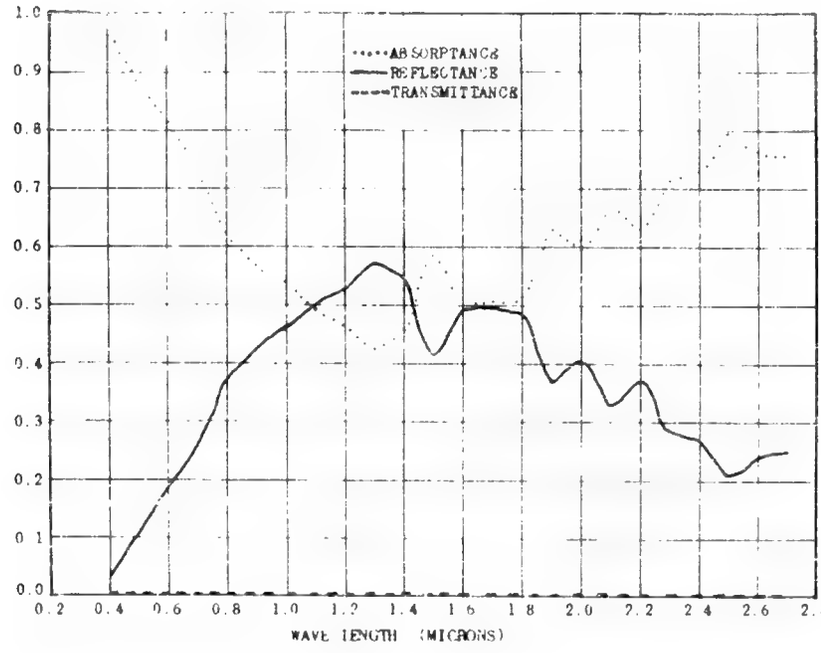

Fig. 17 Spectral Characteristics of Used Yellow Broom Straw

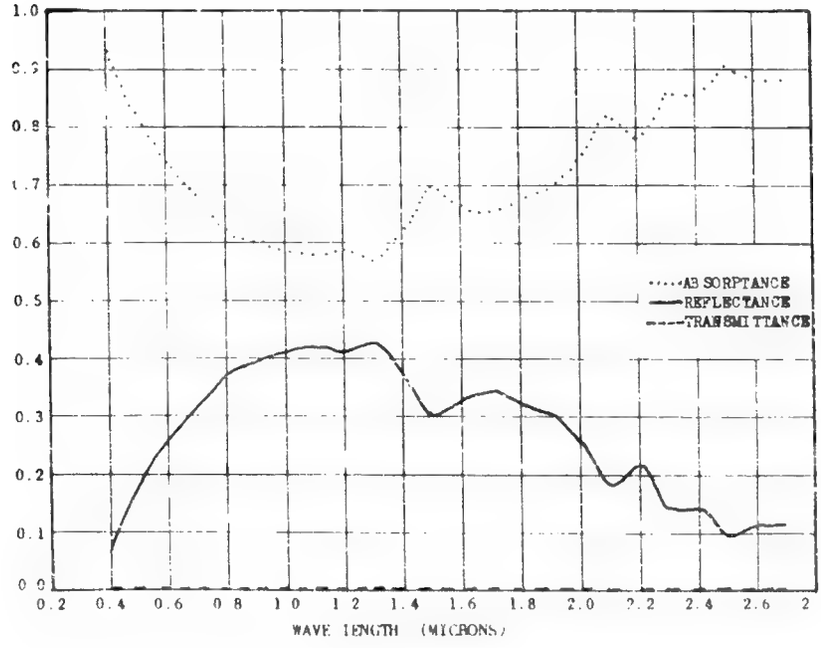

Fig. 18 Spectral Characteristics of Tan Tampico Fiber Scrub Brush
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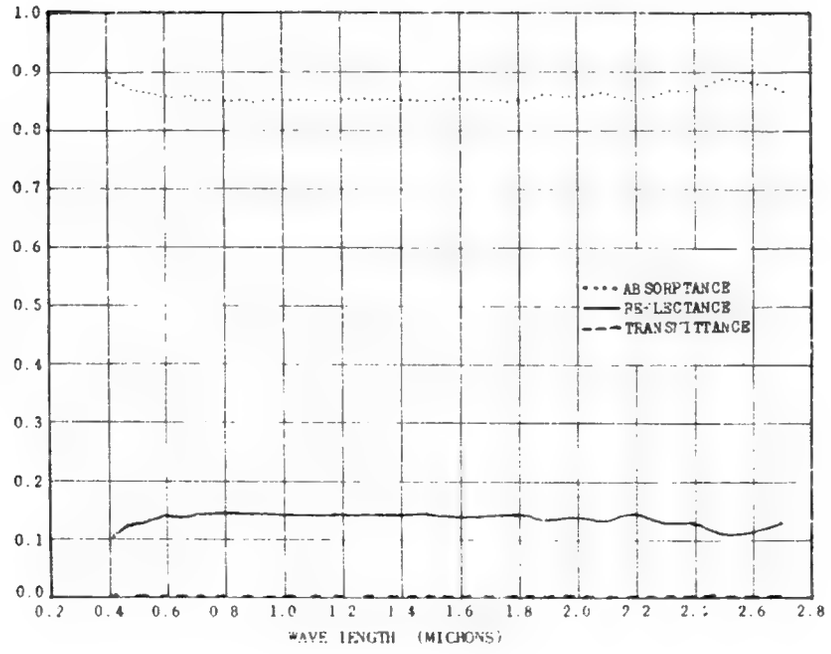

Fig. 19 Spectral Characteristics of Oily Gray Dust Mop

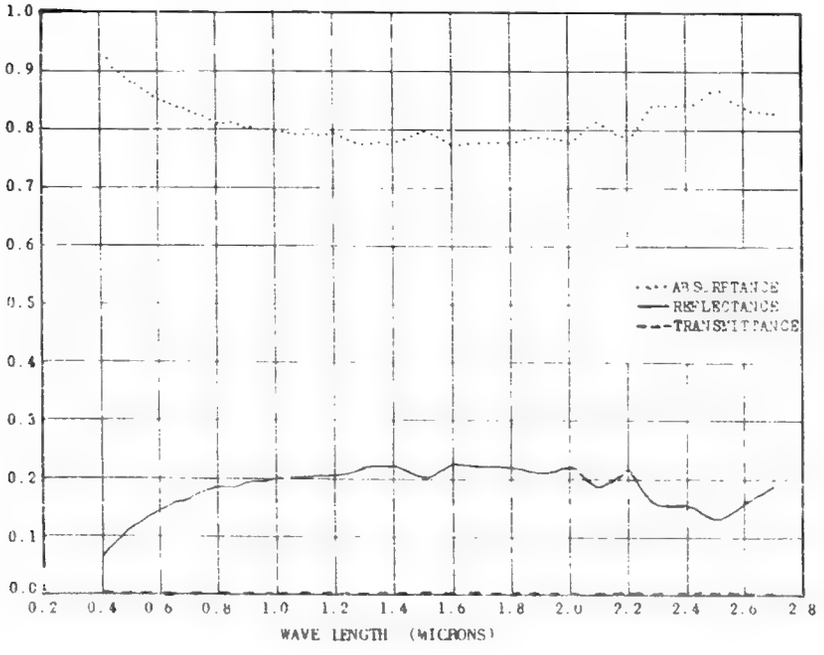

Fig. 20 Spectral Characteristics of Oily Gray Cotton Waste
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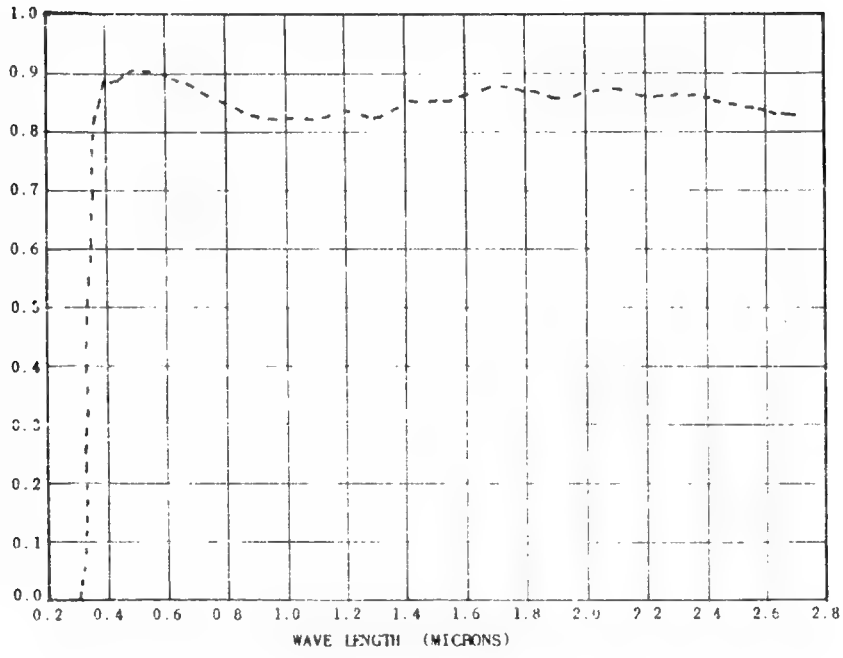

Fig. 21 Transmittance of Single Strength Sodium Window Glass

RADIANT ABSORPTANCE COEFFICIENTS

Forest Products Nos.	Sample Description	Radiant Absorptance	
		2600°K	6000°K
454	Cotton tape from Venetian Blind, old, cream color, 0.032" thick	0.41	0.43
318	Window shade, oiled, new, green, 0.014" thick	0.72	0.87
128	Bristol board, 3-ply, dark, 0.017" thick	0.34	0.64
100	Crepe paper, green, 0.0056" thick	0.28	0.62
137	Bristol board, 10-ply, white, 0.044" thick	0.30	0.23
164	Bristol board, 3-ply, white, 0.017" thick	0.30	0.16
429	Sheeting, unbleached cotton, 0.014" thick	0.26	0.21
424	Flannel, wool, black	0.45	0.73
438	Rayon twill lining, beige, 0.008" thick	0.22	0.31
401	Cotton denim, blue, washed, 0.025" thick	0.53	0.77
408	Acetate shantung, black, 0.0075" thick	0.28	0.66
441	Rayon twill lining, black, 0.008" thick	0.28	0.62
461	Rayon marquisette curtain, ivory-white, 0.0296" thick	0.28	0.20
417	Rayon acetate drapery, wine	0.24	0.53
196	Shredded newspaper	0.54	0.55
209	Excelsior, Ponderosa Pine, light yellow	0.53	0.53
362	Broom straw, yellow, old, used	0.58	0.71
248	Tampico fiber, from used scrub brush, tan	0.68	0.72
353	Dust mop, oily, dry, gray, diameter of fiber 0.061"	0.86	0.86
300	Cotton waste, used, oily, gray	0.80	0.84

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